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QUALITATIVE STUDY OF THE MAGNUS EFFECT BY PLAYING WITH THE DRIVEN SPINNING TOP

Florin D.Grosu[1]., Alina Rapa[2] and Ioan Grosu*[3,4]

[1]Faculty of Medicine, Lucian Blaga University, Sibiu, Romania
[2]ACP Department, Kwantlen Polytechnic University, Metro Vancouver, Canada
[3]Faculty of Bioengineering, University of Medicine and Pharmacy Gr.T.Popa, Iasi
[4]Chemistry Department, Al.I.Cuza University, Iasi, Romania

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ABSTRACT

We report, for the first time, the qualitative study of the Magnus Effect by playing with the new Driven Spinning Top. Experimentation is full of fun and is suitable for STEM (science, technology, engineering and mathematics) activities. Several simple student projects can be realized including a modelling. It is suitable for upper high school students and first years of Physics, engineering university students.

INTRODUCTION

Here we show how Magnus Effect can be studied observing the dynamics of a spinning top. By our best knowledge this is the first time that this is reported.

Magnus effect is a simple application to the Bernoulli law from fluidics. Recently it received an increased attention in school science [1-3] driven by the fever of the World Soccer Championship. It happens when a fluid flows over a spinning cylinder (or when a spinning cylinder moves in a static fluid) (see Fig. 1). Also it happens when a spinning ball is launched [1-4]. On the upper side of the cylinder (Fig.1) the velocities of the fluid and that one of the flow of the boundary layer are added and on the bottom side they are substracted. The dynamic pressures are different on the two sides and a force F_M acts upward. This effect was discovered by Magnus in 1852 and in 1920 Anton Flettner built the first wind-powered ship [5]. In line with references [1-3] we present in the following another application that can be implemented at school-level. Its importance comes from the need of a deep understanding (at the popular level) of the Physics behind the observations that could help to improve the activity of extracting clean energy from wind.

In the next section we present the new driven spinning top and we justify why it helped to observe the Magnus effect in its dynamics. Section 3 suggests new toys based on Magnus effect and its importance in the search for clean energy from wind.

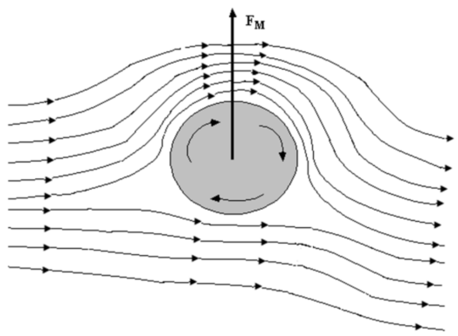


Fig 1 A spinning cylinder moving from right to left in a fluid. F M is the Magnus force perpendicular on the flow and the axis of rotation.

Corresponding author:* **Ioan Grosu
Faculty of Medicine, Lucian Blaga University, Sibiu, Romania

The Driven Spinning Top

The spinning top is an old and much beloved toy. Toy industry created many types of spinning tops with different shapes, dimensions, colors, used different materials. Many patents have been written with different improvements[6]. In spite of its diversity it remained uncontrollable. Using two permanent magnets [7] (one on the axis at its top end and another one moved by hand above) it was turned controllable (Fig.2).

Moving slowly by hand the 2nd permanent magnet the spinning top will move horizontally without mechanical contact and without impeding the rotation. This is the Driven Spinning Top (DST) [7] . We will restrict here (for simplicity) to spinning tops with a cylindrical shape. DST can be used to be launched from the same point on an inclined plane. More than this it can be transported (without modification of rotation) in any point by using the suspended version (Fig. 2b) and by shaking the hand the two magnets can be put apart without impeding the rotation.

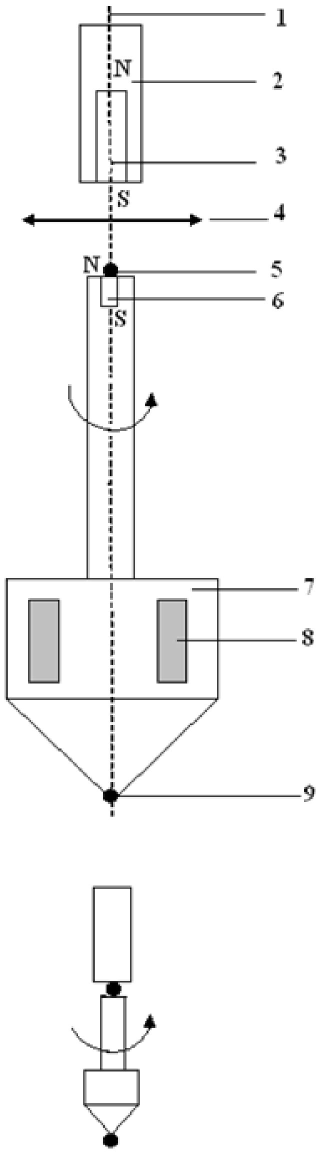
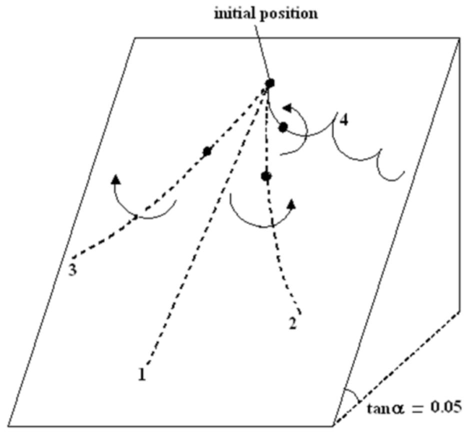


Fig 2 a).(top) The driven spinning top (1-axis , 2-wood,3-2nd magnet moved by hand ,4-movement by hand , 5-an iron ball,6-1st permanent magnet ,7-wood,8-stainless steel that increase the moment of inertia and the time of rotation,9-an iron ball), b) (bottom) A schematic of a suspended spinning top that can be transported everywhere.

We can drive it to a certain point and moving away the 2nd magnet we let the spinning top free to move downward on an inclined plane. We expect the trajectory will be along the gravitational gradient (Fig.3(1)). By repeated experiments we find out that the spinning top move like in Fig.3 (2) or (3) depending on the sense of rotation. This is the main result of this paper. More than this, changing the angle of inclination of the plane an exotic trajectory (Fig.3(4)) can be observed. This unexpected trajectories are possible because Magnus force (Fig. 1) is perpendicular to the velocity.



By our best knowledge, this is the first report of a Magnus effect on a spinning top[8].

This happened because the spinning top had a status of an uncontrollable object. So nobody dared to look for something deterministic in its dynamics. Another explanation could be that spinning tops were rotating a short time. Our DST has a hollow stainless steel cylinder inside that increase the moment of inertia and implicit the time of rotation.

Time of rotation of the spinning tops is usually of 15-20 seconds but the rotation of ours lasts up to 120 seconds. Our DST has a stick of 11cm that permits to be rotated using both hands like in [9, 10].

If we look at the historic pictures [6] with children playing spinning tops they stay in a circle because the trajectory is curved. Otherwise they could stay in two lines. Usually the people were not interested in the trajectory of the spinning tops they enjoyed just the curious behavior of staying vertical when rotating. A special spinning top with a pencil at its bottom show the trajectory (Fig.4)

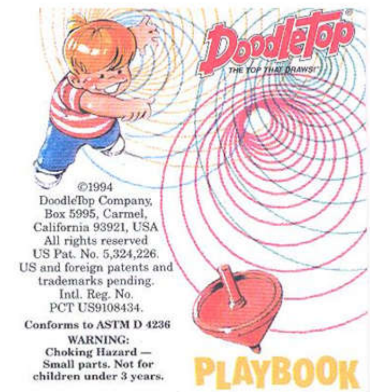


Fig 4 Scan of the label of Guggenheim Museum 1994 Doodle Top. No straight line trajectory…just curved trajectory.

Future Work

A window fan or a vacuum cleaner can supply/replace the wind. Popular use of this toy on an inclined plane can help to rise the interest on extracting wind energy. Naval and aeronautical applications are covered by scientific literature [5,11]. Theoretical [12,13] and experimental [5,11] work is necessary. Intense use of this toy can trigger proposed problems in Physics Olimpiads. We are acustomed with situations when a force is collinear with velocity but in this case the force is perpendicular on velocity. This is much more difficult to predict (Fig. 3 (4)). It is less intuitive. It is self-understood that this effect cannot be observed in vacuum.

After enough experimentation a modeling [1,2,3] is needed to get more progress. Models [1], [3] consider angular frequency constant but it is not. On a certain material a dependency of frequency of rotation on time can be approximated (by pieces) using a stroboscope and introduced in the model. Also the friction can be approximated. If the qualitative explanation is simple the quantitative one needs more work: to build a model with a good agreement between simulation and experiment. For example to reproduce the trajectories from Fig.3. We believe that such a work at the popular level can help to remove the pessimistic statement concerning applicability of Magnus effect: ´The system does not seem to have been economically successful" [14].

Changing the inclination of the plane the trajectories will be different in shape. The initial rate of rotation can be realized to be constant for different experiments by using the string with the same length (Fig. 5). Different lengths will determine different initial rotation rates. If in the model we have some constants that are uncertain (for example the friction coefficient) then a fitting between the trajectory from the simulation and that one from experiment can be of help.

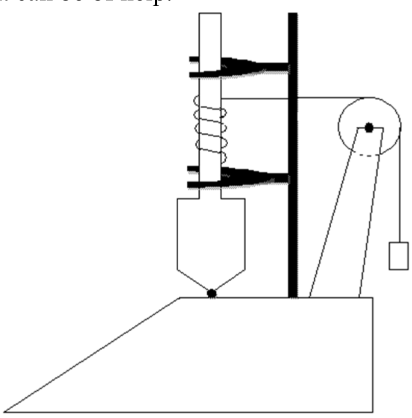


Fig 5 Two forks and a pulley can be used to have the same initial spinning rate. Changing the length of the string the initial spinning rate can be changed quantitatively and reproductively.

We suggest that toy industry can make toy cars with a vertical spinning cylinder (driven by an electric toy motor) that could be used on inclined planes. More than this remote controlled toy cars to have a vertical spinning cylinder. The driving will be more challenging and competition games more intriguing. The same with the toy ships. If the cylinder will be at the rear than it can be used to change the direction. The Magnus force is determined by the spinning rate, the flow velocity and the surface roughness. All these parameters can be changed and investigated in simple student projects.

References

1. Anders Floren, Phillippe Jeanjacquot, Dionysis Konstantinou, Andreas Meir, Corina Toma and Zbigniew Trzmiel (2016) Screwball Physics in iStage 3 Football in Science Teaching, www.science-on-stage.de/iStage3_materials
2. Laura Howes (2016), Sport in a Spin, Science in School, issue 35, p.15, Spring 2016
3. V.Timkova and Z.Jeskova (2017), How Magnus Bends the Flying Ball-Experimenting and Modelling, *Phys.Teach*.55, 112.
4. J W M Bush (2013). The aerodynamics of the beautiful game, in Sport Physics, Ed.C. Clanet, Les Editions de l'Ecole Polytechnique, p.171-192.
5. Jost Siefert (2012), A review of the Magnus effect in aeronautics, Progress in Aerospaces Sciences 55,p.17-45
6. L.Bas, A.Verdoorn (2011), The lost art of spinning tops, ISBN 9090260129, www.worldcat.org/lost-art-of-spinning-tops/712013981
7. I.Grosu and D. Featonby (2016), The driven spinning top, Physics Education 51,033002.
8. Preliminary results have been presented at two domestic conferences (a- Colocviul International de Fizica "Evrika-Cygnus", Iasi, 28-30 Aug. 2015, b- Fizica si Tehnologiile Educationale Moderne, Iasi,13-14 Mai,2016)
9. First video http://www.youtube.com/watch?v=Vpo_T8sq2SM%2F
10. Second video http://www.youtube.com/watch?v=LauHlSuq_ms
11. A.Sedaghat (2014), Magnus type wind turbines, Prospectus and challenges in design and modeling, Renewable Energy 62, 619-628.
12. K.E.Kenyon (2016), On Magnus effect, Natural Science 8,49-62
13. J.A.Farrow, J.Hue, R.Miller and C. Checklin (2014). A2_5 Rotation Aviation, *Journal of Physics Special Topics*, November 13.
14. T.B.Greenslade Jr. (2006), A Forgotten Magnus-Effect Demonstration, The Physics Teacher 44,552.

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